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Review Article

Natural Gums as Pharmaceutical Binders: Current Perspectives and Future Opportunities

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ABSTRACT

Natural binders play a crucial role in tablet formulation by imparting cohesiveness, mechanical strength, and modulating drug release behavior. Growing concerns regarding the cost, environmental impact, and safety of synthetic binders have increased interest in plant-derived polymers as sustainable alternatives. Among these, okra gum obtained from Abelmoschus esculentus has shown promising binding efficiency and release-modifying properties. Studies indicate that natural binders improve granule flow, compressibility, tablet hardness, and drug release profiles in both conventional and modified-release systems. However, challenges such as batch-to-batch variability, microbial contamination, and stability issues require proper standardization and quality control. Overall, natural binders, including okra gum, represent a biodegradable, cost-effective, and eco-friendly approach for sustainable tablet formulation in modern pharmaceutics.

INTRODUCTION

In pharmaceutical tablet formulations, binders are essential excipients that serve mainly to give powders cohesion and guarantee the creation of mechanically robust compacts during the tableting process. A material's compressibility, hardness, and disintegration behavior are all directly impacted by its binding strength. Stronger binders usually produce more durable tablets, but they may also take longer to disintegrate, which could have an impact on the kinetics of drug release. The efficacy of polymeric binders during granulation is also greatly influenced by their film-forming and adhesive qualities, which eventually affect the quality of the tablets.[1]

Because of their portability and convenience, tablets are the most commonly prescribed dosage forms globally. Pharmaceutical binders,

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sometimes called adhesives, are a key category of excipients utilized to enhance tablet formulations.[2]

One kind of excipient that is added to a tablet formulation to improve its mechanical characteristics and release profile by inter-particle bonding is called a binder. They may be semisynthetic, synthetic, or natural. Pharmaceutical binders that are synthetic or semi-synthetic are costly, scarce, and nonrenewable. According to research, these artificial additives are dangerous for the environment as well as for humans.[3]

Gastroretentive Drug Delivery System

The primary strategy of stomach targeting is to prolong the gastric residence time of the formulations. The strategy is suitable for drugs that are mainly absorbed or work in the stomach or upper GIT, or for drugs that are not stable in intestinal alkaline conditions. [4] The gastroretentive delivery systems can also be used for sustained or controlled drug release, which is beneficial for reducing the fluctuations of systemic drug concentrations, decreasing the frequency of administration and increase patient compliance to drugs.[5] Although a large number of gastroretentive formulations were studied, there is little progress on the clinical translation. The most frequently used gastric retention preparations are gastric floating, gastric expandable, and mucoadhesive and high-density formulations.

Local Targeting to GIT

Based on the physiological characteristics of different GIT sites, oral drug delivery systems are commonly used to deliver drugs specifically targeting the GIT. The main local targeting delivery strategies are summarized in Figure no.1

Figure no.01:- Local targeting drug delivery systems to GIT after oral administration.[6]

Oral medication is the most common form of drug administration because of advantages such as convenience of drug administration via the oral route, patient preference, cost-effectiveness, and ease of large-scale manufacturing of oral dosage forms. Around 60% of established small-molecule drug products available commercially are administered via the oral route. Current estimates indicate that oral formulations represent about 90% of the global market share of all pharmaceutical formulations intended for human use. Around 84% of the best-selling pharmaceutical products are orally administered and are currently valued at $35 billion, with an annual growth rate of 10%.[7]

The compliance of patients to oral formulations is generally higher than that to other parenteral routes such as intravenous, subcutaneous, and intramuscular injections, as well as to inhalation for asthma medications. Furthermore, orally administered drugs can be targeted to particular regions within the gastrointestinal (GI) tract for localized treatment of pathological conditions such as stomach and colorectal cancers, infections, inflammations, bowel diseases, gastro-duodenal ulcers, and gastroesophageal reflux disorders.[8] Despite these advantages, the development of oral formulations presents several challenges, which are mainly attributed to the physicochemical properties of drugs, including poor water solubility and membrane permeability. In addition, the absorption of drugs can be limited by their poor chemical and biological stability, as well as by physiological barriers, including pH, efflux transporters, and metabolic enzymes. Further, some drugs can cause local irritation and nausea.[9]

Over the last four decades, numerous studies have focused on understanding the mechanism of drug absorption and transport, intestinal transit, microenvironment of the GI tract, and drug stability in the GI fluids.[10] Thus, the elaboration of oral drug delivery systems necessitates a thorough understanding of the physicochemical properties, GI permeability, biological barriers, pharmacokinetics, and pharmacodynamics of drugs.[11]

Tablet

The Indian Pharmacopoeia defines pharmaceutical tablets as solid, flat, or biconvex dishes that are used as unit dose forms. They are made by compressing a medication or a combination of medications, either with or without diluents. A compacted solid dosage form that contains medications, either with or without excipients, is called a tablet. Depending on the quantity of therapeutic ingredients and the intended manner of administration, they fluctuate significantly in size, weight, and shape.[12]

The tablet is the most commonly used dosage form among all available options due to its ease of administration, lower production costs, and elegance.[13] The aesthetic attributes such as color, texture, mouthfeel, and taste masking are determined by coating techniques. This coating technology has certain limitations or drawbacks, and to address these limitations. Tablet is one of the best alternatives. The present work aims to comprehensively review the formulation, characterization, and challenges in the development of Tablet in Tablet dosage form.

The principal benefit of tablets as a dosage form is that they offer a precise medication dosage. Every tablet has to have an established quantity of medication and has to be consistent in diameter, appearance, and weight. Orally administered tablets, once ingested whole, ought to easily break down in the stomach. This characteristic embodies a significant formulation paradox: tablets must be strong enough to endure the challenges of coating and packaging processes, yet they should also be able to release the drug quickly. The breakdown of the compact occurs due to aqueous fluids infiltrating the tablet's time-residual pore structure, causing it to burst apart.[14]

Properties[15]

1. It should be a sophisticated product that possesses its own identity and is devoid of any flaws, including chips, cracks, discoloration, and contamination.

2. Must be strong enough to endure the stresses of shock experienced during its production, packaging, transport and dispensing.

3. Must be physically stable enough to keep its physical attributes over time.

4. Has to be capable of delivering the pharmaceutical agent(s) into the organism in a way that can be predicted and repeated.

5. Has to be capable of delivering the pharmaceutical agent(s) into the organism in a way that can be predicted and repeated.

6. Must possess appropriate chemical stability over time to prevent changes to the medicinal agent.

Advantages[16]

1. Tablets are a unit dosage form that offers the most precise, steady dose with the least amount of content variability.

2. Patients can easily use, handle, and carry tablets.

3. Tablets have a sophisticated and appealing appearance.

4. In terms of their physical, chemical, and microbiological characteristics, tablets are the most stable dosage form. They are also produced at a relatively high speed and at a lower cost than other dosage forms.

Disadvantages[17,18]

1. In the case of unconscious patients and children, swallowing presents a challenge.

2. Due to their amorphous nature and low density, some drugs resist being compressed into dense compacts.

3. It may be challenging to create a tablet that offers sufficient or complete drug bioavailability for medications that have suboptimal wetting and dissolution characteristics but whose ideal absorption occurs in the upper GIT.

4. Drugs that are sensitive to oxygen, have an objectionable odor, or taste bitter may need to be encapsulated or coated. In these situations, capsule might provide the best option at the lowest cost.

5. Irritant effects on the gastrointestinal mucosa caused by certain solids (e.g., aspirin).

6. Potential bioavailability issues arising from gradual disintegration and dissolution.

7. Drugs that test bitter, have an unpleasant smell, or are oxygen-sensitive may need to be coated or encapsulated. In certain situations, capsules could be the finest and most affordable option.

Various Types of Tablet[19]

Various types of tablets are being developed and used recently Table 1 describes the various types of tablets used now days.

Table 1: Different Type of Tablets

Oral Tablets for Ingestions	• Standard compressed tablet • Multiple compressed tablet: Compression coated tablet/layered tablet/Inlay tablet • Modified release tablet • Delayed action tablet • Targeted Tablet: • Floating tablet/colon targeting tablet • Chewable tablet • Dispersible tablet
Tablets for Oral Cavity	• Lozenges and troches • Sublingual tablet • Buccal tablet • Dental cones • Mouth dissolved tablet

Tablets Administered by Others Routes	• Vaginal tablet • Implants
Tablets for Solution Preparation	• Effervescent tablet • Hypodermic tablet • Soluble tablet

Various Novel/Advanced Types of Tablet Drug Delivery System:

Now a day's various kinds of advanced tablets were developed and used according to Table 2.

Table 2: Different Types of Novel Tablet Drug Delivery Systems

Sr no.	Types of Tablet
1	Oral extended release tablets
2	Osmotic pressure controlled tablets
3	Multi-layered tablets formulations
4	Gastroretentive buoyant drug delivery system
5	Mucoadhesive drug delivery systems
6	Targeted drug delivery system
7	Colon specific drug delivery
8	Miscellaneous
9	Vaginal tablets
10	Ion exchange resin system
11	Rapid disintegrating tablet

Excipients

Excipients are additive substances incorporated into tablet formulations to enhance the bulkiness, disintegration, dissolution rate, and bioavailability of the drug. The interaction study of the drug and excipient is conducted using Infrared Spectrum to determine the stability of both the excipients and the drug.[20]

Common excipients used in tablets [21,22]

Diluents:-

1. Provide bulk and enable accurate dosing of potent ingredients
2. Diluents serve as fillers to achieve the necessary tablet bulk when the drug dosage alone is insufficient for this purpose. Also utilized to enhance cohesion, allowing for the application of direct compression
3. Examples:- Carbohydrate compounds such as lactose, dextrin, glucose, sucrose, and sorbitol
4. Inorganic substances such as silicates, salts of calcium and magnesium, and chlorides of sodium or potassium

Binders, granulating agents, compression aids:-

1. Hold the tablet components together while providing shape and mechanical strength.
2. To create cohesive compacts for tablets that are directly compressed.
3. Examples:- Primarily natural or synthetic polymers such as starches, sugars, sugar alcohols, and cellulose derivatives.

Disintegrants:-

1. Help the tablet spread in the gastrointestinal tract, liberating the active substance and enlarging the area for dissolution
2. Incorporated into a tablet formulation to aid in its fracturing or disintegration upon contact with water in the gastrointestinal tract.
3. Examples:- Compounds that either swell or dissolve in water, such as starch, cellulose derivatives, alginates, and crospovidone.

Glidants :-

1. Enhance the flow of powders in the process of tablet production by minimizing friction and adhesion among particles. They are also utilized as anti-caking agents.

2. Glidants aim to facilitate the flow of granules or powdered substances by minimizing the friction among the particles.

3. Examples:- Colloidal silicon anhydrous and other silica compounds.

Lubricants:-

1. Lubricants serve the purpose of averting the sticking of tablet materials to the surfaces of punches and dies, lessen the friction between particles and have a positive effect on the flow rate of the tablet granulation.

2. They act similarly to glidants, but may reduce the rate of disintegration and dissolution. While the characteristics of lubricants and glidants vary, certain substances like talc and starch serve both functions.

3. Examples:- Stearic acid and its derivatives (such as magnesium stearate)

Tablet coatings and films:-

1. Shield the tablet from environmental factors (such as air, light, and humidity), enhance its resistance to physical stress, conceal its odor and flavor, facilitate ingestion, and contribute to its identification. May be utilized to alter the release of the active substance. May include flavors and color additives.

2. Examples:- Film coating with natural or synthetic polymers is now used instead of sugar (sucrose).

3. For enteric coatings that postpone the release of the active ingredient, polymers that do not dissolve in acid, such as cellulose acetate phthalate, are utilized.

Colouring agents:-

1. Enhance patients' acceptance, assist in identification, and avert counterfeiting. Enhance the stability of drugs sensitive to light.

2. Primarily synthetic dyes and natural colors.

3. Colors and dyes in a tablet serve three functions:

a) Concealing of medications with an unusual hue

b) Item Identification

c) Manufacturing of a more refined product.

4. Examples:- It is also possible to utilize compounds that are natural food pigments themselves.

Flavoring Agents:-

1. Chewable tablets require flavoring oils. The oil is typically introduced in a dry format, like spray-dried beadlets.

Absorbents:-

1. If the product contains a substance that has a high affinity for water, it is necessary to include absorbents in the tablet formulation.

2. If they are present, hygroscopic materials make the blend wet and hard to manage during production.

Techniques for Making Tablets

1. Direct compression

2. Wet granulation

3. Sintering Method

1) Direct compression:-

Medicinal Without a doubt, the most straightforward method for tablet production is direct compression (DC). It is sufficient for the active ingredient to be correctly mixed with suitable excipients prior to compression, according to DC. In addition to the ease of formulation and production, direct compression offers significant benefits such as lower capital, labor, and energy expenses for manufacturing, as well as the elimination of water use for granulation with drug substances that are sensitive to moisture.[23]

Applicability of direct compression

Whether DC applies to a particular drug substance is primarily determined by dose. The three essential elements for effective tableting are the flow and compactability of the compression mix, as well as ensuring uniform drug content in both the mix and the finished tablets. It is probable that all of these factors will be influenced by the amount of drug administered. A low dose of around 10 mg or less, a medium dose of approximately 10 mg to 50 mg, and a high dose of about 50 mg are chosen. In the case of low-dose pharmaceuticals, the excipients play a major role in determining flow and compaction of the compression mix. The main objective is to ensure satisfactory content uniformity both in the blend and in the tablets. For drugs with medium doses, the flow of the compression mix may be crucial, while for drugs with high doses, both flow and compaction rely heavily on the characteristics of the drug substance. It is estimated that direct compression as a manufacturing technique accounts for up to 50% of formulations in the United States.[24]

2) Wet granulation

The most common method for agglomerating or granulating in pharmaceutical powder blends involves the use of a granulating liquid, followed by wet sizing and drying. the sector is wet granulation. The wet granulation process consists of three main steps: the powder blend is wet massed with a granulating liquid, then sized by weight, and finally dried.[25]

Important steps involved in the wet granulation[26]

1. Combination of the drug(s) and excipients
2. Preparation of adhesive solution
3. Combining the binder solution with the powdered mixture to create a wet mass.
4. Coarse screening of the wet mass with an appropriate sieve (6-12 screens).
5. Dehydration of moist granules.
6. Dry granules are to be screened using an appropriate sieve (14-20 screen).
7. Combining screened granules with disintegrant, glidant, and lubricant.

Limitation of wet granulation[27]

1. The major drawback of wet granulation is its expense. The process is costly due to the demands of labor, time, equipment, energy, and space.
2. Material loss throughout different processing stages
3. For moisture-sensitive or thermolabile drugs, stability can be a significant issue.
4. The complexity increases due to the presence of several processing steps, which also complicates validation and control.

3) Sintering Method

1. Sintering is the process of applying heat to connect neighboring particle surfaces in a bulk of powder or in a compact.

2. In conventional sintering, a compact is heated in a controlled atmosphere under air pressure at a temperature below the melting point of the solid elements.

3. Sintering was shown to cause alterations in the hardness and disintegration time of tablets kept at high temperatures.

4. Sustained release matrix tablets have been made using the sintering process to stabilize medication release.[28]

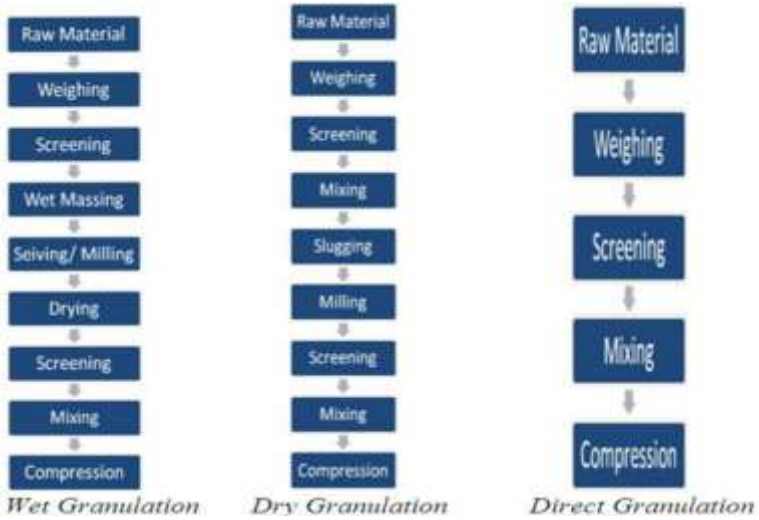

Fig no. 02:- Processing Steps in Wet Granulation, Dry Granulation and Direct Granulation[29]

1) Precompression

During precompression, tablets are partially formed and the precompression roller is smaller than the compression roller, resulting in a lower applied force. A machine that provides multistage compression with high precompression and an optimal main compression force achieves the best compression efficiency. For items that experience brittle fracture, implementing precompression with a force greater than that of main compression leads to increased tablet hardness. It is reported that using rollers for precompression and for the main compression that are of similar dimensions, so as to apply forces that are also similar, leads to optimal tablet formation.[30]

2) Main Compression:-

In the course of main compression, the energy applied is converted into the creation of interparticulate bonds. Upon the application of a force within a die, the particles initially rearrange themselves to create a structure with reduced porosity when subjected to very low forces. Subsequently, the particles attain a condition in which any additional relative movement is precluded; thus, an increase in the force applied results in fragmentation and/or deformation of the particles.[31]

3) Decompression:-

Once the applied force is taken away, a set of stresses arises within the tablet due to elastic recovery. The tablet needs to possess sufficient mechanical strength to accommodate these stresses; otherwise, failure of its structure may happen. If elastic recovery is pronounced and rapid, capping or laminating of the tablet may occur. During decompression, if the tablet experiences brittle fracture, it can lead to the

formation of failure planes as surfaces fracture. Tablets that do not cap or laminate can relieve stresses through plastic deformation.[32]

4) Ejection:-

In the compression cycle, the final step is ejection from the die. The ejection phase necessitates a force to overcome the adhesion between the die wall and the compact surface, as well as additional forces to finalize the tablet's ejection.

The force required for the ejection of a tablet is the unique peak force needed to begin the process of ejection by disrupting the adhesion between die wall and tablet. The second stage consists of the force needed to push the tablet up against the die wall, while the final force is necessary for ejection. When lubrication is insufficient, variations in this process can occur due to a slip-stick condition between the tablets and dies wall. This results in ongoing formation and breakage of tablet die–wall adhesion. Lubricants reduce stress patterns, thereby decreasing the likelihood of materials capping or laminating. [33]

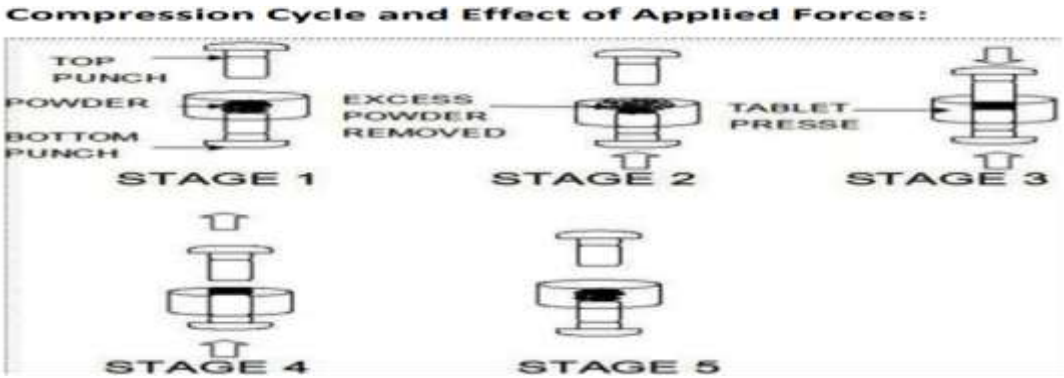

Fig no. 03:- Compression cycle and Effect of Applied forces

Validation of Tablet

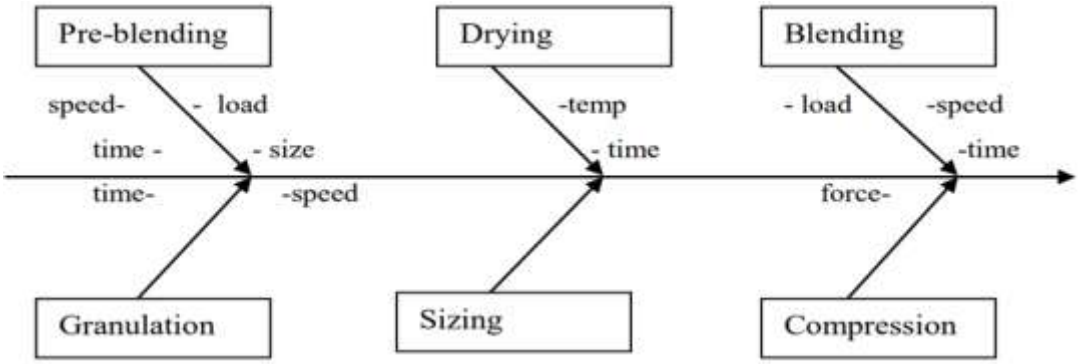

Fig no. 04:- Process flow diagram for process validation of tablet.[34]

Types of Tablets[35,36]

1) Compressed tablets

These tablets are created through compression and do not have any special coating. They are created from powdered, crystalline, or granular substances, either individually or in conjunction with a binder, disintegrates, controlled release polymer, lubricant, and diluents, and often include colorant.

2) Sugar-coated tablets

Compressed tablets with a sugar coating are known as sugar-coated tablets.This coating can be colored and useful for concealing drug substances that have an unpleasant taste or smell, as well as for safeguarding materials that are prone to oxidation.

3) Film coated tablets

These tablets are compressed and coated with a delicate film made of water-soluble material. Several substances that have the ability to form a film are employed.

4) Enteric coated tablets

These are compressed tablets coated with a substance that withstands gastric fluid but disintegrates in the intestine. Enteric coating can be applied to tablets containing medicinal substances that are inactivated or destroyed in the stomach, those that irritate the mucosa, or those intended for delayed release of medication.

5) Multiple compressed tablets

These are compressed tablets made by more than one compression cycle; Layered tablets, Pressed - coated tablets.

6) Controlled released tablets

It is possible to create compressed tablets that release the medication gradually over an extended duration. Therefore, this dosage form is also known as a sustained-release and prolonged-release dosage form.

7) Tablets for Solution

Tablets that are compressed and intended for use in preparing a solution or adding a specified characteristic to a solution must have labels indicating that they should not be ingested.

8) Dispensing tablets

These tablets offer a user-friendly amount of strong medication that can be easily mixed into liquids and powders, eliminating the need for weighing out small amounts.

9) Immediate Release Tablets

Immediate release tablets are designed to disintegrate and dissolve quickly, thereby releasing the medications. An appropriate pharmaceutically acceptable diluent or carrier may allow for immediate release, as long as it does not significantly extend the drug's release and/or absorption rates.

10) Buccal or sublingual tablets

These tablets are small, flat, and oval-shaped. Tablets designed for buccal administration by placing them in the buccal pouch may dissolve or erode slowly, so they are formulated and compressed with enough pressure to create a hard tablet.

Problems with Existing Oral Dosage Form [37]

1. Due to possible tremors, the patient finds it challenging to consume powders and liquids. Dysphasia can lead to gastrointestinal ulceration due to physical barriers and adherence to the esophagus.

2. The act of swallowing solid forms of medication such as tablets and capsules poses challenges for young adults whose muscular and nervous systems are still developing, as well as for elderly patients dealing with dysphasia

3. Because liquid medicinal products (suspensions and emulsions) are stored in

multidose containers, it can be challenging to ensure that each dose is uniform.

4. Due to the potential for irritation of the oral mucosa, patients declined to use buccal and sublingual medications.

5. The cost of products is the primary factor, as parenteral formulations are the most expensive and uncomfortable.

Natural binders:-

Excipients are additives used to transform active medicinal substances into a pharmaceutical dosage form appropriate for patient administration.[38] An essential part of tablet composition is the binder. It is utilized to create a cohesive bond between active pharmaceutical ingredients (API) and inactive substances (other excipients). In order to give flexibility and strengthen the inter-particulate bonding, binders are added to the tablet formulation.[39] Correspondingly, binding agents in tablet formulations results in attaining specific tablet mechanical strength and drug release characteristics.[40]

To accomplish various pharmaceutical goals, different binders have varying mechanical strengths and drug release characteristics. A thorough understanding of binder qualities for improving strength and the interaction between different material constituents should be taken into account while making the tablet. For this reason, there is ongoing interest in developing novel excipients for use as tablet binders. In tablet formulation, a variety of natural and synthetic polymers are employed as binders. Because of their low cost, low toxicity, biocompatibility, and environmentally acceptable manufacturing, natural binders like starch, gums, and mucilage are commonly utilized.[41]

Gums can be categorized as natural, semi-synthetic, modified, or synthetic due to their hydrophilic nature. Acacia, ghatti, karaya, locust bean, albizia, khaya, guar, tragacanth, and xanthan are among the gums that are extracted or exuded from the bark of different plants' stems, branches, and roots. The plant groups Anacardiaceae, Combritaceae, Meliaceae, Rosaceae, and Rutaceae are renowned for producing gums. There are several explanations for why plants produce gums, such as as byproducts of regular plant metabolism.[42] In order to give the tablet formulation flexibility and strengthen the interparticulate bonding, binders are added.[43]

Gums are often polysaccharides, which are naturally occurring polymeric substances derived from both woody and nonwoody plant parts, including bark, seeds, sap, roots, rhizomes, fruit, leaves, and plant gums. These substances are frequently utilized in the creation of pharmacological dosage forms. Gum is mostly used as a binding agent in tablet.[44]

The efficiency of natural gum and mucilage as a binder in tablet formulation was the focus of the current study.[45] Binders are the agents which hold various powders together to form a tablet. They impart cohesiveness to the granules to improve compression and flow properties which derived the hardness of tablet.[46] To accomplish various pharmaceutical goals, different binders have varying mechanical strengths and drug release characteristics. A thorough understanding of binder qualities for improving strength and the interaction between different material constituents should be taken into account while making the tablet.[47]

For this reason, there is ongoing interest in developing novel excipients for use as tablet binders. Tablet formulation uses a variety of polymers, both natural and synthetic, as binders.

Because of their low cost, low toxicity, biocompatibility, and environmentally acceptable manufacturing, natural binders like starch, gums, and mucilage are commonly utilized.[48] Although batch-to-batch variability and other restrictions have prompted innovations like chemically modified or co-processed binders for better consistency, natural binders enable sustainable tablet formulation due to their renewable sources.[49]

Advantages of Natural Gums in pharmaceutical science[50]

1. Natural Binders are widely used in the pharmaceutical and food industry as excipients and additives due to their low toxicity, biodegradable, availability and low cost.

2. Additionally, they can be utilized to alter the drug's release, which will affect the integrated drug's absorption and subsequent bioavailability.

3. They can be used to modify drug release, which affects the integrated medications' absorption and bioavailability.

4. Because natural binders are inexpensive, accessible, biodegradable, and have minimal toxicity, they are frequently employed as excipients and additives in the food and pharmaceutical industries.

5. They serve as vehicles that deliver the integrated medication to the site of absorption, ensure that the dosage is precise and accurate, and, when necessary, enhance the medications' organoleptic qualities to encourage patient loyalty.

6. They should test dosage forms both when they are being manufactured and when patients are using them.

Disadvantages of Natural Gums in pharmaceutical science[51,52]

1. Microbial contamination is a possibility because the gums' equilibrium moisture content is typically 10% or higher, they are primarily carbohydrates, and they are exposed to the outside world during production. Preservatives and careful handling, however, can stop this.

2. Variation from batch to batch: Gum production is influenced by seasonal and environmental variables, whereas synthetic manufacturing is a regulated process with set amounts of materials.

3. Uncontrolled hydration rate-The percentage of chemical constituents in a specific material can vary due to differences in the collection of natural materials at different times, as well as variations in region, species, and climate conditions. It is necessary to create appropriate monographs on the gums that are available.

4. Storage leads to a reduction in viscosity—usually, when gums interact with water, the formulations' viscosity rises. Because of the complicated characteristics of Gums (ranging from monosaccharides to polysaccharides and their derivatives), it has been discovered that viscosity decreases after storage.

Binder types

1] Resource-based classification[53]

Examples of natural binders include carboxy methyl cellulose, ethyl cellulose, and methyl cellulose.

1. Animal Source: Chitosan, Chitin, etc.
2. Marine Source: such as algimic acid and agar
3. Microbiological Source: Xanthan, dextran, etc.
4. Plant Source: Tragacanth, Acacia, etc.

2] Source -based classification[54]

1. Chitosan, chitin, chondroitin, and sulphat are derived from animals.
2. Marine sources: laminarin, alginic acid, and agar
3. Bacterial and fungal microbial sources: dextran and xanthan
4. Plant source: Exudates from shrubs and trees, such as gum ghatti and Arabica.
5. Guar gum, locurt gum, and other seed gums are examples.

3] Shaped- based classification

1. Linear: Amylose, cellulose, and pectin, for instance
2. Branched: Short branches, such as xylan and xanthan
3. Branch on branch—Amylopectin, Gim Arabic, for instance

4] Charge-based classification[55]

1. Non-ionic: Example – Guar gum, xanthan gum, dextrin
2. Anionic: Example – Alginic acid, pectin, karaya gum
3. Cationic: Example – Chitosan, chitin, cationic guar gum
4. Amphoteric: Example – Carboxymethyl chitosan, N-Hydroxyldicarboxyethyl chitosan
5. Hydrophobic: Example–Cetylhydroxyethyl cellulose, polyquaternium

CATEGORIZATION BASED ON THEIR USE[56]

1. Solution binders: These are solubilized in a solvent (for instance, water or alcohol is utilized in wet granulation methods). Examples are gelatin, cellulose, derivatives of cellulose, polyvinyl pyrrolidone, starch, sucrose, and polyethylene glycol.
2. Dry binders: These are incorporated into the powder mixture, either following a wet granulation step or as part of a direct powder compression (DC) formulation. Illustrations comprise methyl cellulose, cellulose.

OKRA GUM

Okra gum is among these types of gums and has seen a rise in popularity in the pharmaceutical industry over the past few decades. It has been demonstrated to be a promising excipient for modifying drug release from tablets of various APIs in solid dosage forms.[57] Okra gum serves as an emulsifying agent and stabilizer in liquid dosage forms, specifically in emulsions, and acts as a suspending agent in pediatric suspensions.[58] Okra gum has been utilized in nasal drug delivery systems due to its gel-forming properties and mucoadhesive characteristics.[59] Earlier studies have compared the binding ability of okra gum with that of PVP, cornstarch , and gelatin and have

shown that okra gum is a better binder than these routinely used binders. However, there is no study signifying the binding strength of okra gum in quantitative terms.[60]

In this study, the binding strength of okra gum was assessed using two different methods based on the principle that two surfaces, initially bonded by applying adhesive material between them, are separated by applying a load. Furthermore, the binding efficacy of okra gum was illustrated through an analysis of the properties of granules and tablets produced via wet granulation with a model drug and varying concentrations of okra gum serving as a binder. The studied characteristics include the bulk properties of granules and the tablet's hardness, friability, disintegration time, and drug release patterns. The results were compared to those of tablets made with a traditional binder, specifically pre-gelatinized starch, which is widely used in the pharmaceutical industry.[61]

Preparation of the Aqueous Extract of Okra

Okra gum was obtained from the fresh pods of Abelmoschus esculentus using a previously described extraction method from the literature.[62] To achieve this, okra pods (approximately 0.25 kg) were cleaned, dried at ambient conditions (about 25 °C), and cut into small pieces of roughly 1 inch in length after taking off the calyces. These slices (with a weight of 0.10 kg) were placed in a pan, ~1.5 L of distilled water was added, and they were heated at ~60 °C for 4 hours with occasional stirring. A muslin cloth was used to filter the mixture, and the resulting aqueous extract was refrigerated at 4–6 °C.[63]

Isolation of okra gum

The gum okra was precipitated from the aqueous extract by adding three portions of acetone (~250 mL each) and filtering the resulting precipitates with filter paper after each addition. The precipitate was placed in an oven at approximately 40 °C until it reached a constant weight. The dried gum was ground using a pestle and mortar, sieved through a mesh of number 20, and kept in an air-tight glass container at room temperature until it was needed again.[64]

Methods

Extraction of mucilage from the pods of okra fruit

The pods of okra fruits were used to extract okra gum. The fruits were cleaned, washed, sliced, crushed, and macerated in distilled water for 10 hours with intermittent stirring. The mucilage was passed through a white muslin cloth to extract the gum, and acetone was added to precipitate the extracted gum. The gum was subsequently filtered under vacuum to eliminate acetone and was dried in a desiccator.[65] The specific gravity, pH, water content, total ash content, acid insoluble ash, water soluble ash, and microbial limit of Okra gum binder were measured according to the recommendations of the U.S. pharmacopoeia.[66]

Evaluation of Powder Blend

The prepared mixture is assessed using the following tests.

1. Angle of repose
2. Bulk density
3. Tapped density
4. Hauser's ratio
5. Carr's index
6. Angle of repose

1. Angle of repose[67]

The funnel method was used to measure the angle of repose. A funnel was used to hold the blend, which had been weighed with precision. The funnel was adjusted to a height where its tip just made contact with the top of the pile of blend. The blend of drug (as solid dispersion) and excipient was allowed to flow freely through the funnel onto the surface. The diameter of the powder cone was measured, and the angle of repose was computed using the following formula

$$\text{Tan } \theta = h/r$$

$$\text{Angle of repose } (\theta) = \tan\text{-}1\ (h/r)$$

Where,

h = height of the powder pile

r = radius of pile circle

Flowability expected	Angle of repose (degrees)
Excellent / Very Free Flow	25-30
Good / Free Flow	31-35
Fair (discharging aid may not be required)	36-40
Passable	41-45
Poor Flow / Cohesive (active discharging aid required)	46-55
Very Poor Flow / Very Cohesive	56-65
Approximatively no flow	> 66

2. Bulk Density (BD)

Weigh out granules (M) 25g that have been passed through a #20 sieve and place them in a 100ml graduated cylinder. Without compressing, level the powder with care and take note of the apparent volume (V0) Compute the apparent bulk density in gm/ml using the formula below: Bulk density (BD) is calculated as M/Vo

$$\text{Bulk density} = M/Vo$$

Where,

M = mass of powder taken,

Vo = apparent unstirred volume.

3. Tapped Density (TD)[68]

Weigh (M) 25g of granules, which have been passed through a #20 sieve, with precision and transfer them into a 100ml graduated cylinder. Then, using a mechanically tapped density tester that produces a fixed drop of 14±2mm at a nominal rate of 300 drops per minute, raise the cylinder containing the sample and let it fall under its own weight to tap it mechanically. Initially, tap the cylinder 500 times and measure the tapped volume (V1) to the nearest graduated unit. Then, repeat the tapping for an additional 750 times and measure the tapped volume (V2) to the nearest graduated unit. If the difference between the two volumes is under 2%, then volume (V2) is considered the final volume. Determine the tapped density in gm/ml using the following formula

$$\text{Tapped density (TD)} = M/VT$$

Where, VT = Tapped volume or final volume

4. Carr's index[69]

In the field of pharmaceutics, the Carr index is often employed as a measure of a powder's flowability. A Carr index above 25 suggests poor flowability, while a value below 15 indicates good flowability. The Carr index indicates how compressible a powder is The percentage compressibility of the powder mixture was calculated using the following formula, which takes into account the apparent bulk density and tapped density

It is determined by formula

Car`s index (%) =

$$\frac{\text{Tapped density - Bulk density} \times 100}{\text{Tapped Density}}$$

Carr's index (as %)	Flow Type
5 -15	Excellent
12 -16	Good
18 - 21	Fair to passable
23 - 35	poor
33 - 38	Very poor
40	Extremely poor

5. Hausners ratio[70]

By using following formula, the Hausners ratio can be calculated. This serves as an indirect indicator of how easy it is to measure powder flow. A Hausner ratio of less than 1.25 indicates better flow properties than one greater than 1.25.

Flow character	Hausner ratio
1.00 -1.11	Excellent
1.12 -1.11	Good
1.19-1.25	Fair
1.26-1.34	Passable
1.35-1.45	Poor
1.46-1.59	Very Poor

Future Aspects[71]

Natural binders offer significant opportunities for advancement in modern pharmaceutics. Future research and development may focus on the following areas:

1. **Standardization and Quality Control**
   Development of pharmacopeial standards and detailed monographs for natural binders to ensure consistency, purity, and reproducibility in tablet formulations.

2. **Chemical Modification and Co-processing**
   Structural modification (e.g., cross-linking, grafting, derivatization) and co-processing with other excipients to enhance compressibility, flowability, and controlled drug release properties.

3. **Application in Advanced Drug Delivery Systems**
   Exploration of their use in gastroretentive systems, mucoadhesive tablets, floating tablets, colon-targeted systems, sustained-release matrices, and multiparticulate dosage forms.

4. **Compatibility and Stability Studies**
   In-depth drug–excipient interaction studies using advanced analytical tools to evaluate long-term stability and performance.

5. **Scale-Up and Industrial Feasibility**
   Evaluation of large-scale production methods, cost-effectiveness, supply chain sustainability, and performance in high-speed tablet manufacturing.

6. **Nanotechnology and Novel Platforms**
   Investigation of natural polymers in nanocarriers, hydrogels, 3D printing of tablets, and personalized medicine approaches.

7. **Regulatory and Safety Evaluation**
   Comprehensive toxicological, microbial, and regulatory assessments to facilitate global acceptance and commercialization

CONCLUSION

Natural binders have emerged as promising alternatives to synthetic and semi-synthetic excipients in tablet formulation due to their biodegradability, biocompatibility, low toxicity, cost-effectiveness, and renewable origin. Their ability to impart adequate cohesiveness, mechanical strength, and desirable drug release characteristics makes them suitable for both conventional and modified-release tablet systems. Extensive research demonstrates that plant-derived gums, mucilages, and polysaccharides can effectively improve granule flow properties, compressibility, hardness, and overall tablet performance. In addition, natural binders contribute to sustainable pharmaceutical development by reducing environmental impact and dependence on non-renewable resources. However, challenges such as batch-to-batch variability, microbial contamination, uncontrolled hydration behavior, and viscosity changes during storage must be carefully addressed through proper standardization, processing, and quality control measures. Overall, natural binders represent a viable and sustainable approach in modern pharmaceutics, offering significant potential for the development of safe, effective, and eco-friendly tablet dosage forms.

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